Synopsis for
Research Proposal On

"Design of an automated system for musculoskeletal image analysis and interpretation of knee for quicker diagnosis"

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1. **Title**

   "Design of an automated system for musculoskeletal image analysis and interpretation of knee for quicker diagnosis"

2. **Introduction**:

   Medical image processing is one of the major research topics and has become an interdisciplinary research field attracting expertise from applied mathematics, computer engineering, statistics, medicine etc[25]. Now a day's computerised detection /diagnosis system is used as second opinion and has already become a part of the routine clinical work in assisting radiologists to name an example like detection of breast cancer with mammograms [14]. In other words it is known by Computer aided detection /diagnosis (CAD) system. It can improve diagnosis capabilities of physician and reduce the time required for accurate diagnosis. The literature survey reveals that CAD based on imaging is open research problem. Therefore the design and development of CAD can be of immense importance to help in diagnosis/detection of many diseases of the patient [14].

   Automated detection of abnormalities i.e Computer-aided detection/diagnosis (CAD) systems is already used on a large scale still there is scope to improve image interpretation and to provide varieties of decision support tools for healthcare industry.

   The process of diagnosis based on medical images comprises of two fundamental steps: image examination -visual perception and an interpretation (Cognition)[24].

   During the diagnosis process by physician or even by radiologist, these two steps are not error free due to their complexities and human limitation. As many researchers reported that, abnormalities that are clearly present in an image are sometimes not reported by clinicians [17]. Due to lack of expert medical practitioners, every patient is unable to get appropriate diagnosis from specialists always. The cause of the abnormality may have a large impact on the patient's care.

   The musculoskeletal part as knee is chosen in the proposed system because the knee is one of the most complex and delicate joints in the body. It is one of the frequently injured or damaged components of the human motion system [7].

Musculoskeletal conditions are a major burden on individuals, health systems, and social care systems. As musculoskeletal conditions are becoming crucial in large population, there is need of an automated system which can analyse the medical images to assist the medical practitioners for saving their valuable time [17]. The literature survey reveals that various methods are proposed for musculoskeletal image analysis like image enhancement, segmentation, feature extraction etc [2][22]. But the combination of all these aspect is not observed in the literature. However American news dated March 1, 2016, "One in two Americans have a musculoskeletal condition" [16] reported that an estimated 126.6 million Americans (one in two adults) are affected by a musculoskeletal condition. We believe that computer models of the musculoskeletal condition can help to provide a scientific basis for treating disorders and will help to contribute for betterment of society.

Major musculoskeletal conditions are osteoarthritis, rheumatoid arthritis, osteoporosis, and low back pain[16].

Osteoarthritis is a prevalent but poorly understood disease affecting millions of adults. Patients may present with joint pain, often accompanied by articular cartilage and meniscus damage, synovial inflammation, osteophytes, and joint space loss. Articular cartilage loss is a prominent, pathophysiological component [8]. Increases in life expectancy and ageing populations are expected to make osteoarthritis the fourth leading cause of disability by the year 2020 [16].

Osteoarthritis (OA) is the most common form of arthritis where the knee is the most studied joint. Knee OA is recognized as a disease involving entire joint structure, including bone, cartilage, meniscus, ligament, synovial membrane, and synovial fluid where visualization of these structures is necessary for a complete assessment [3]. The main effects of Osteoarthritis OA are the degradation of the articular cartilage together with remodeling and overgrowth of bone. This process causes loss of mobility of the joints. It typically affects large weight bearing joints as hips and knees. Knee joint image segmentation is a very challenging task because of its complexity. MR images have been widely preferred in the literature to realize the segmentation of articular cartilage in the knee joint[7].

In India, the increase in population is enormous. There is insufficiency of trained medical professional in the rural area. As a result of this, many times the medical practitioner are over burdened while diagnosing the patient. So there is a need to have automation n the field of medical diagnosis.

To address this problem, there is a need to design and develop an automated system (CAD) for musculoskeletal image analysis and interpretation of Knee to assist radiologists as well as clinicians to take quick decision.

We propose a system which will acquire musculoskeletal images such as MRI as input and then performs various image processing and analysis steps together for putting the automation in place. Image processing and analysis steps include image enhancement (pre-processing), feature extraction and segmentation and finally Test–Retest Experiment of real time datasets.

2.1**. Image acquisition and pre-processing**

Medical image acquisition devices are X-ray, Magnetic Resonance Imaging (MRI), Computed Tomography (CT) scan CT, Ultrasound, PET/SPECT, EEG/MEG. These techniques are highly dependent on computer technology to generate digital images. MRI is widely used standard medical imaging technique for visualization of internal body structure used in radiology [7]. It allows quantitative evaluation of the cartilage and cartilage deterioration can be detected using MRI. [6]

Image enhancement techniques play a significant role in pre-processing. Image enhancement methods improve the quality of the digital image for further processing. This stage is used to reduce noise and improve the resolution and contrast of the image. Image enhancement techniques such as histogram equalization, gray scale enhancement and adaptive histogram equalization are applied to scanned MRI images generally.

Pierre Dodin et al [2] have presented the double echo steady state (DESS; Siemens) sequence which was used on 3T apparatus for cartilage volume assessment, as it enhances the contrast between the cartilage and synovial fluid.

2.2 **Feature Extraction**

Transformation of image into set of features is known as feature extraction. Useful feature of the image extraction is a challenging task to extract good set for classification. There are many techniques for feature extraction such as texture feature, Gobar feature, feature based on wavelet transform, principal component analysis, minimum noise fraction transform, discriminate analysis, decision boundary feature extraction [25]. Large number of algorithms has been proposed for the extraction of features from knee MRI images. Weighted histogram equalization algorithm retains the shape and trend of the original gray histogram and also retains image details to a large extent [26]. Contrast Stretching and Image Sharpening techniques for enhancing edges of MRI knee images shows much better result as compare to Contrast Stretching on Adaptive Thresholding methods [27].

2.3 **Image Segmentation**

Image segmentation is the process of partitioning a digital image into multiple segments for better understanding and processing. Even though there are many algorithms developed for knee joint cartilage segmentation still there is a scope for better segmentation and precise quantification of cartilage because of the complexity involved in segmentation algorithms.

The knee is made up of four major bone segments: the femur, the tibia, the fibula and the patella (knee cap). The knee joint contain soft tissues such as ligaments, cartilages and so on. The ligaments provide stability and strength to the knee joint [3]. Cartilages cover the patella, tibia and femur in the regions where the bones contact one another. Cartilages allow the bones to slide freely on each other.

Even though there are many algorithms developed for knee joint cartilage segmentation still there is a scope for better segmentation and precise quantification of cartilage because of the complexity involved in segmentation algorithms. Knee joint image segmentation is a very challenging task because of its complexity. Deformable models perhaps are one of the most active and successful segmentation method, widely used in knee segmentation[6]. In the 2-D active contour algorithm developed by Claude et al. a local coordinate system (LCS) is developed for the femoral and tibia cartilage boundaries

for the measurement of thickness and volume. Active appearance models is not suitable for the knee joint segmentation due to its basic assumption [6]

Various Image segmentation methods are as follows :

- Thresholding Approach
- Region based Segmentation Methods : Segmentation algorithms based on region mainly include following methods
    - Region Growing
    - Region Splitting and Merging
- Segmentation based on Artificial Neural Network
- Segmentation based on Clustering
- Deformable Methods
- Markov Random Field Model
- Atlas Guided Approach

2.4 **Registration Between Bone Surfaces**

Image registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, and/or by different sensors.

The majority of the registration methods consists of the following four steps [20].

- Feature detection
- Feature matching
- Transform model estimation
- Image resampling and transformation

The multitude of challenges inherent in performing image registration can be better addressed by distilling the problem into four distinctive components[18]. Automated image registration (AIR) is a sophisticated and powerful image registration algorithm. It was developed by Woods, the feature space it uses consists of all the pixels in the image, and the search space consists of up to fifth-order polynomials in spatial coordinates x, y

(and z, if 3-D), involving as many as 168 parameters. The goal is to define a single, global transformation [19].

Pierre Dodin et al [2] have proposed a method in which registration of bone surface is done by using images of individual at different times. The images of an individual at two dates t1 and t2 should be computed using a registration function to obtain a spatial correspondence between bone surfaces to compensate for the different positioning of the individual during each examination .Registration is performed in the image coordinate space using closet point method.

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- Feature detection
- Feature matching
- Transform model estimation
- Image re-sampling and transformation

3. Literature Survey

Computer aided diagnosis, as we see it today, is hardly used as a part of the routine clinical work. Medical image analysis has much more challenges specially related to knee diagnosis. This is an interesting research topic. Existing work typically fall of in one of two categories: Segmentation and Feature Extraction.

Attempts to fully automate cartilage segmentation and quantitative analysis of MRI images are ongoing in several research groups [1][2][15][22].

The first fully automatic knee cartilage segmentation study was presented by Folkesson et al. [28], who segmented only the medial articular cartilage between the femur and tibia with a voxel classification using MRI images of healthy and osteoarthritis populations. Their approach involved a region-growing algorithm based on the binary classifiers as k-nearest neighbours (k-NN).

Extensive research efforts have been made by C. Huang; L. Shan et al. [1] to automate diseased region detection of knee MRI imaging based on Gaussian hidden Markov model (GHMM). The proposed method deals with the spatial heterogeneity of cartilage

progression across both time and OA subjects. Automatic cartilage segmentation method presented in this paper is extension of multi-atlas segmentation approach.

A variety of techniques have been proposed for segmentation of knee joint. According to the classification reported by Andrea Aprovitola et al. [7], most commonly used knee bone segmentation methods from MRI images are thresholding approach, deformable methods, Markov Random Field Model and Atlas Guided Approach [1].

Pierre Dodin, Jean-Pierre Pelletier et al. [2] have proposed the automatic segmentation algorithm for human knee cartilage volume quantification from MRI. In this paper Bayesian decision criterion allows the automatic separation of the cartilage and synovial fluid using 3T scanner and a knee coil imaging. It provides accurate and precise quantification. The proposed algorithm automatically segments human knee cartilage from 3-D MR images, allowing continuous assessments of human osteoarthritis knee cartilage volume. It uses texture analysis to detect the external boundary of the cartilage. Important challenging issue discussed by these authors is the separation of cartilage from synovial fluid to reduce intra subject variability.

A fully automated segmentation methodology of knee features proposed by G. Tamez-Pe [8] produces reproducible cartilage volume, thickness, and shape measurements valuable for the study of OA progression. Main goal of their study was to present and test an advanced, fully automated image analysis tool for articular cartilage and bones in the knee, and to measure articular cartilage volume, surface area, thickness, and bone shape changes that occur over a 2 year period in a small cohort with a spectrum of early OA. The precision achieved using the automated tool is 0.6% for the entire femoral cartilage plate.

A variety of approaches have been proposed for knee cartilage segmentation but very lass work is been presented for automated segmentation of knee meniscus. Amir Faisal, Siew-Cheok Ng, Siew-Li Goh et al. [3] have implemented an active contour for image segmentation femoral condoyle, meniscus, and tibia plateau in order to determine the area and the position of the meniscus. The presented strategy inside the variation level set method adapted the size of the local window in order to avoid being trapped in

homogeneous regions during the segmentation process. Multiple active contours framework LREK (MLREK) image segmentation was presented to assess of knee meniscus for degeneration and displacement. Bharath Ramakrishna et al. [15] developed an Automatic Computer – Aided Detection System for meniscal tear on knee by using MRI Images of patients aged from 15 to 73. The menisci have an essential function in force transmission across the knee. Injuries to the menisci are common. The indications for repair should be expanded, as the results of partial menisci may deteriorate over time [11]. The medial and lateral meniscus of the knee is a crescent shaped cartilage pad between the femur and the tibia bones of knee joint. The meniscus acts as a smooth surface for the joint to move on. It helps in distributing forces of weight on joint surfaces and provides stability by preventing lateral movement of the knee joint. In osteoarthritis (OA) knee joints menisci undergoes degeneration. In sports knee injuries normally result in menisci tears [15][3]. Peter Larking [12] has done classification of meniscus tear in four different types as Longitudinal, Horizontal, Radial and Flap and meniscus injuries can be classified on their appearance, location, shape, extent and origin.

Jianzhong Qian et al. [23] have published a patent on CAD as mark-free computer-assisted diagnosis method and system for assisting diagnosis of abnormalities in digital medical images using diagnosis based image enhancement in United States Patent.

4. Statement of Problem

The above literature survey reveals that there is a need to develop effective techniques for the analysis of musculoskeletal images of knee in order to aid medical practitioners in the interpretation of medical images particularly in the rural area. Further due to lack of expert medical practitioners in the rural area, every patient is unable to get appropriate diagnosis and treatment from specialist always.

The proposed system will be helpful in automating diagnosis of musculoskeletal diseases / disabilities and will do assistance role to aid clinicians in the interpretation of medical images and thereby improve the diagnostic process.

Main objective of the work can be described as follows by the problem, which is expressed as follows.

"Design of an automated system (CAD) for musculoskeletal image analysis and interpretation of MRI or CT images of human knee to assist medical practitioners for quicker diagnosis "

The specific objectives of the research are further divided into following sub problems.

List of Objectives:

1. To develop a technique for image enhancement of musculoskeletal image related to Knee.
2. To propose an efficient algorithm for image segmentation of Knee articular cartilage.
3. To present an efficient algorithm for image segmentation of meniscus of knee.
4. To develop an effective Computer-aided detection /diagnosis system for automatic detection of abnormalities such as meniscus tear, articular cartilage damage and other in the knee joint to assist medical practitioners for quicker diagnosis.
5. To train, develop and test the CAD system for real time dataset in order to evaluate the observation under consideration.

5. Proposed Scheme

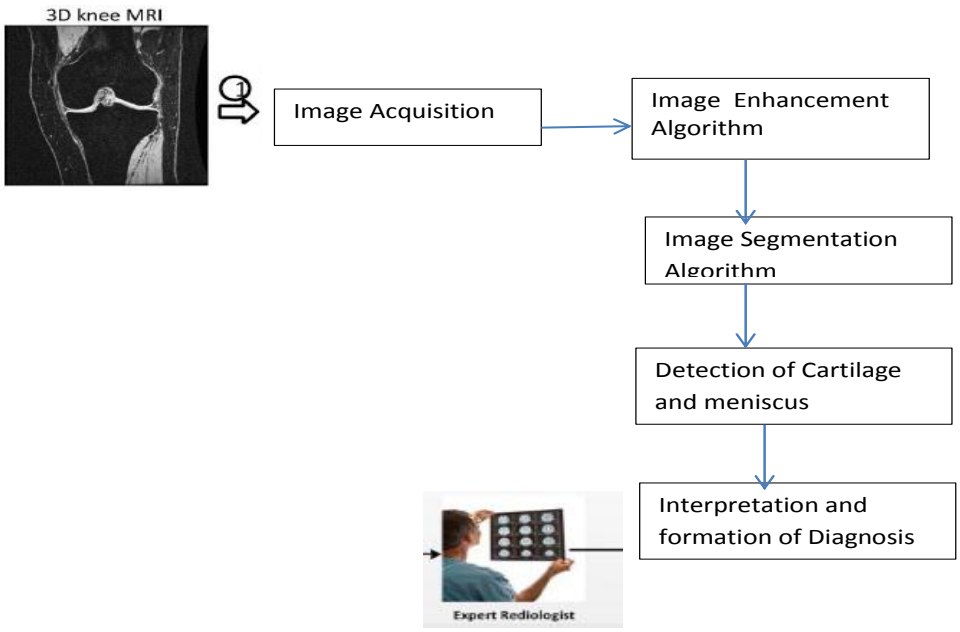

Figure 1 . Proposed CAD System for Knee

The architecture of proposed research work is shown in Fig 1.

Proposed research work will be divided in to multiple steps as follows:

1. **Development of efficient method for enhancing musculoskeletal images acquired from CT or MRI**

Image enhancement is need to be performed to reduce noise and improve quality of image. We will develop an efficient technique which will reduce the noise without disturbing the edges of image with better performance and make the rest of stages more reliable.

2. **To propose an algorithm for image segmentation of articular cartilage.**

Image Segmentation and defining the region of interest is an important approach and most time consuming part in image analysis. Fully automated method will be presented for segmenting articular cartilage of knee by taking into consideration accuracy and computation time required to present the task.

3. **To present an algorithm for image segmentation for the detection of the knee meniscus tear.**

Image segmentation is required in order to identify area and position of knee meniscus. Quantification of knee meniscus degeneration and displacement in the image requires simultaneous segmentation of femoral condoyle, meniscus, and tibia plateau. An efficient algorithm will be presented to detect meniscus tear with better performance.

4. **To develop a CAD system for automatic detection of knee abnormalities for quicker diagnosis.**

An efficient CAD system will be for automatic detection of abnormalities such as meniscus tear, articular cartilage damage and other in the knee joint to assist medical practitioners for quicker diagnosis. Analysis and Performance evaluation of the CAD system will be done.

6. **Implementation**

A tentative time schedule of the research work planned is given below

Sr. No.	Research Activity	Schedule
1.	Further detailed literature survey	May 16 to July 16
2.	Collection and creation of database of musculoskeletal images and implementation of various medical image processing teshniues	Aug 16 to Oct 16
3.	Design of efficient algorithm for enhancing musculoskeletal images acquired from CT or MRI	Nov 16 to March 17
4.	Proposes an algorithm for image segmentation of articular cartilage	April 17 to Aug 17
5.	Proposes an algorithm for image segmentation to check the knee meniscus tear.	Sep 17 to Jan 18
6.	Merging together previous two algorithms	Feb 18 to April 18
7.	To develop a CAD system for automatic detection of knee abnormalities for quicker diagnosis.	May 18 to Sep 18
8.	Performance evaluation	Oct 18 to Feb 19
9.	Thesis write-up, revision and correction	Feb 19 to May 19

7. Conclusion

In this research work we shall attempt to develop Computer aided detection (CAD) diagnostic system for automatic detection of abnormalities such as meniscus tear in the knee and articular cartilage segmentation and others of musculoskeletal images. An efficient algorithm will be designed for image enhancement as well as segmentation of knee from 3D MRI images to detect articular cartilage and meniscus tear with improved accuracy compare to already existing techniques. Proposed method will help to detect diseased region of knee using MRI/CT image and automated analysis of medical imaging will be used to assist radiologist.

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Research Scholar **Research Guide**

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